RAPID SUBSTITUTION

A strategy to slash the use of oil in the US, reduce pollution, and save trillions of dollars to turbocharge the transition to clean energy.

A Deep Dive

June 2022

www.RapidSubstitution.com

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Who’s Behind Rapid Substitution?

The ideas and analyses put forth here are the brainchild of Paul Klemencic and his team.

Paul Klemencic, founder of Skibo Energy, was an oil and gas industry insider for two decades. His energy sector expertise includes 18 years at Chevron Corporation, where he gained particular knowledge about drilling and refining power management solutions, as well as insights into the challenges of adding new oil supply and the stopping and starting of oil production.

In the early 2000s, Paul realized and embraced the need to dramatically and permanently decrease our world's dependence on oil. As an industry insider, he tried to convince management in the oil and gas industries that, for the good of both the future of the business and the planet, they must begin moving toward a strategy of powerful social, economic, and political shifts necessary to accomplish that goal. This was a message that was so heretical it was met with full-fledged resistance.

Paul left the industry and began applying his technical knowledge of oil production and energy markets to developing the strategy of **Rapid Substitution.** He assembled a team of analysts to work with him on further research, background information, communications, outreach, and implementation of the strategy.

The **Rapid Substitution** team is responsible for the Deep Dive document, as well as the website (www.rapidsubstitution.com), social media and blog posts, and advocacy work focused on accelerating the energy transition using the **Rapid Substitution** strategy.

Introduction

America's current transportation system doesn't work for consumers, businesses, or the environment. In 2019, the country used 19.4 million barrels of oil every day. At an average price of $64/barrel, it means American consumers, businesses, and governments spent more than $450 Billion on oil that year!

This is a huge burden on households. The average household spends more than $2,000/year on gasoline for transportation. The burden is highest on the poorest American who spend over six percent of their household expenditures on gasoline.

That enormous price tag is only a small part of the cost we pay for our oil. Our military engages in costly activities around the globe to keep oil flowing. Pollution emitted by oil wells and refineries contaminate the environment. Fumes from power plants, diesel trucks, and gas burning vehicles fill our air.

Then there is climate change. American consumption of oil is a significant contributor to a global problem that is already making the planet's forest fires hotter and bigger, its droughts longer and more severe, its storms more destructive and deadly.

Rapid Substitution envisions a different approach to energy. Enormous benefits can derive from purposely accelerating the transition from fossil fuels to clean energy. Specifically, by switching from gasoline-powered cars to electric vehicles (EVs), we will have a cheaper, cleaner, more efficient transportation system.

Due to the difficulties involved with stopping and starting oil production, a relatively small decrease in oil consumption can result in a drastic reduction in oil prices. This would save American households, businesses, and governments hundreds of billions of dollars per year, reducing local air pollution and carbon emissions, while building public support for even faster energy transition.

These benefits can be realized by replacing as little as five percent (5%) of our gasoline-burning vehicles with cleaner, zero-emission alternatives.

Rapid Substitution

Rapid Substitution is a strategy to dramatically reduce the cost of oil through accelerated reduction of oil consumption. Based on analysis of historic oil market dynamics, this can be accomplished with a relatively small reduction in oil consumption. Accomplishing this will require private sector investment, smart government policy, and public initiative.

Based on the inelastic nature of oil production and our analysis of historic oil markets and oil supply curves, we estimate that a rapid drop in oil consumption of a few percent can reduce oil prices by over one half, generating hundreds of billions of dollars in savings for consumers.

Due to the inelastic supply of oil, relatively small changes in quantity demand can result in disproportionate reductions in price.

How Rapid Substitution Impacts the Demand for Oil

To understand why **Rapid Substitution** works, it is important to understand the supply curve of oil. Two primary factors explain why the supply of oil that can be produced at any given time is *relatively* fixed.

1. In the short term, only a certain amount of oil can be extracted from the ground at a reasonable cost, namely from working wells in established fields with the necessary infrastructure already built around them.

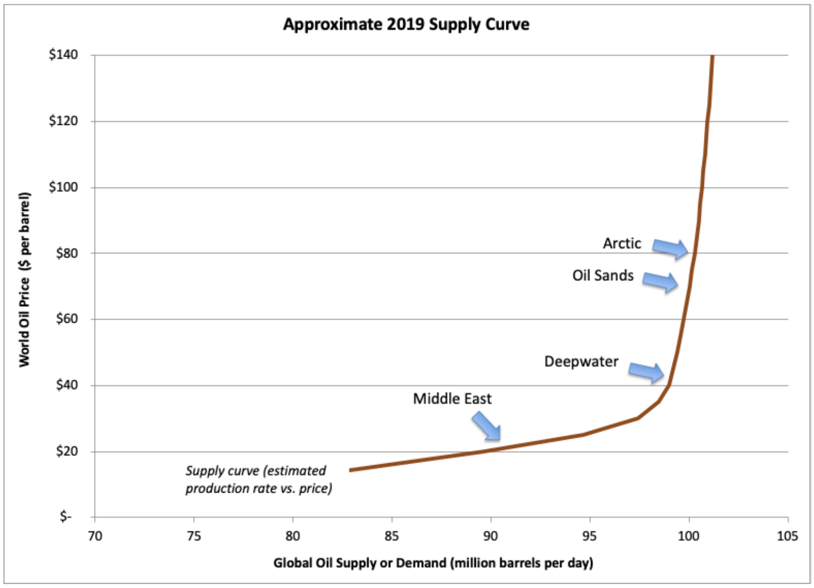
2. Discovering and developing new sources of oil, then constructing the production and distribution infrastructure to service them requires considerable time and capital investment.

Consequently, over the short term, rapid increases in oil demand have a relatively muted effect on the quantity of the global oil supply. Instead, because of market forces, as consumers compete for a limited supply, increased demand usually drives up the price of oil. Similarly, when the supply is unexpectedly limited for some reason, such as a war or conflict in an oil-producing region, prices go up as buyers compete for the remaining supply. Other producers (with the exception of some countries like Saudi Arabia) cannot increase production fast enough to make up the difference, so the only option is for prices to go up.

The technique of hydraulic fracturing (fracking) has changed oil markets since it introduced new supplies and allowed companies to increase production relatively more quickly. However, beginning production on a new permit still takes most companies six to nine months.

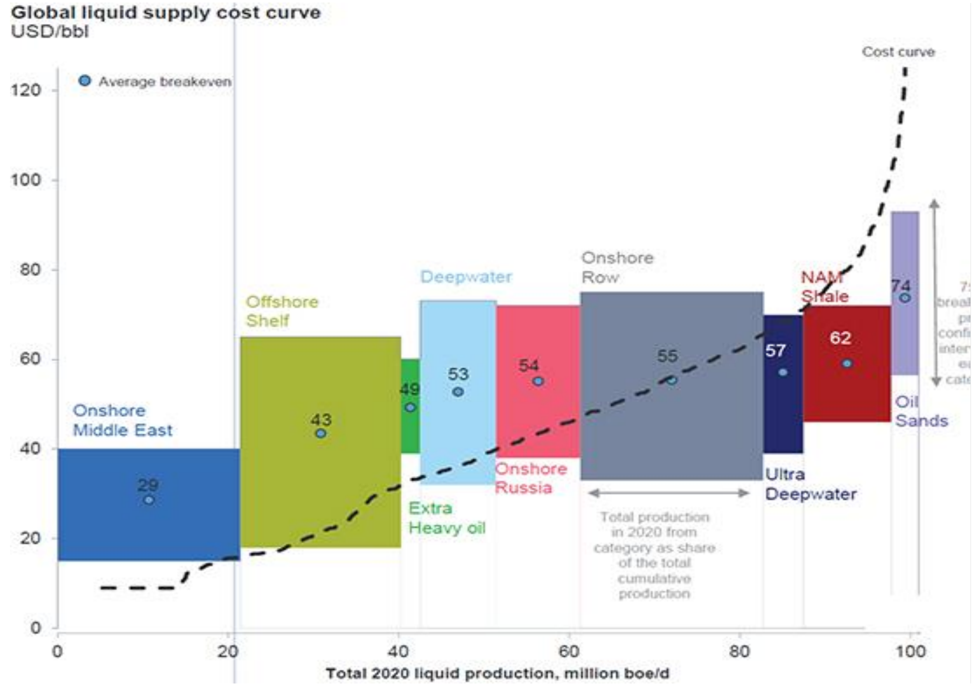
For most of the 2010's, fracking kept a ceiling on oil prices, as production would increase along with prices. However, the latest round of "capital discipline" by fracking companies means that they are not increasing production as oil prices rise. According to a March 2022 survey by the Federal Reserve Bank of Dallas, nearly sixty percent (60%) of US Exploration and Production Firms who responded to the survey cited, "Investor Pressure to Maintain Capital Discipline" as the "primary reason that publicly traded oil producers are restraining growth despite high oil prices."[1]

Consider the following graph which details the approximate components of the Oil Supply Curve for 2019, showing the relative production of oil sources around the globe and the cost of a barrel of oil from that source. The dynamics of oil production create a supply curve that traces a long period where gradual price increases are met with gradual production increases, followed by a steep upturn in price as demand outpaces supply, reflecting the increasing difficulty and cost of finding and developing new oil sources.



Source: EIA, Rystad Energy, Rapid Substitution Researchers

Below is a similar chart produced by the International Monetary Fund which shows the cost curve for oil production. Note how steeply the curve increases as production exceeds 90 million barrels of oil per day.



Source: International Monetary Fund, Rysted Energy[2]

Compared to the world's more easily extracted oil, such as from the vast fields in Saudi Arabia, producers require higher prices to justify the much more costly exploration, leasing, and drilling for that new oil, as well as getting that oil to market. Examples include development of wells in deep water and Arctic situations, along with oil derived from less conventional sources, such as tar sands.[3] At some point, however, the supply of developed oil hits a limit where no amount of new demand or price increase can generate further, near-term increases in production capacity.

The fact that tar sands and other unconventional methods of oil extraction have become an increasingly greater percentage of global oil production since 2000, when prices rose dramatically, is testament to both the steady growth in oil demand and the increasing difficulty and expense of finding and developing new production.

Oil Elasticity – a Brief History

One metric to understand the effect that a drop in oil demand has on price is a factor called "Demand Price Elasticity." In economics, elasticity refers to how sensitive one factor is to another. In this case, demand for oil does not respond much to the price of oil. Many people still must commute to and from or drive for work even if the price of gasoline doubles.

On the other hand, recent history indicates that a relatively small, short-term drop in oil demand leads to an exponential drop in oil price.

We saw evidence of this in 2008 when over a six-month period, a three-percent (3%) drop in the demand for oil[4] resulted in a seventy-percent (70%) plunge in the price of oil[5], and again in Spring 2020, when a sudden, pandemic-driven decline in demand briefly resulted in negative prices for oil futures. We assume that production equals demand since storage volume is relatively marginal.

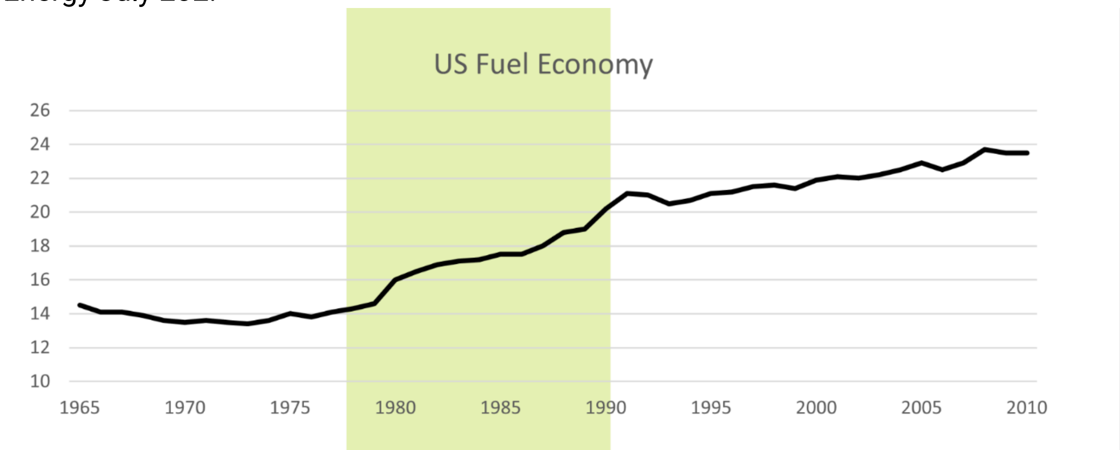
Of course, those were short-duration shocks that caught suppliers off guard, and they may not provide an accurate assessment of how markets might respond to a more gradual and anticipated decline in oil demand, such as will occur as Electric Vehicles (EVs) become an increasing percentage of the world's fleet.

If a more gradual drop in oil demand results in a similar disproportionate drop in oil prices (utilizing the long-term Demand Price Elasticity figure), we expect that as EVs replace gasoline-powered vehicles, oil prices will fall dramatically and then stabilize by 2030 at just above the cost of production, which will be in the vicinity of $30 a barrel.

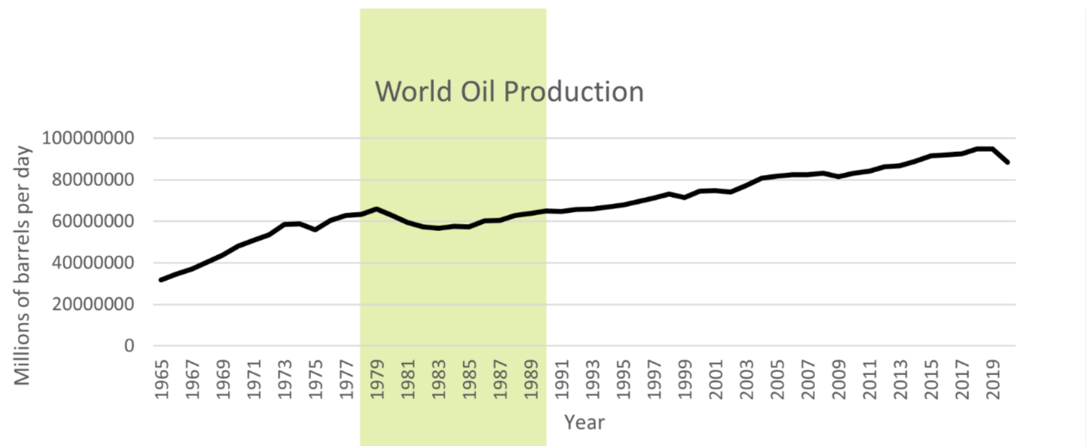
For evidence of how this could work, we look back to the mid-1970s, when the introduction of Federal CAFE (Corporate Average Fuel Economy) standards for vehicle efficiency contributed to a sharp decline in oil demand that resulted in much lower oil prices for almost a decade.

First implemented in 1978[6] in response to declining U.S. control of oil markets to the OPEC cartel (and rising oil prices), CAFE standards were initially intended to double the average fuel economy of the new passenger vehicle fleet, a gradual process to be implemented over a roughly twelve-year period.

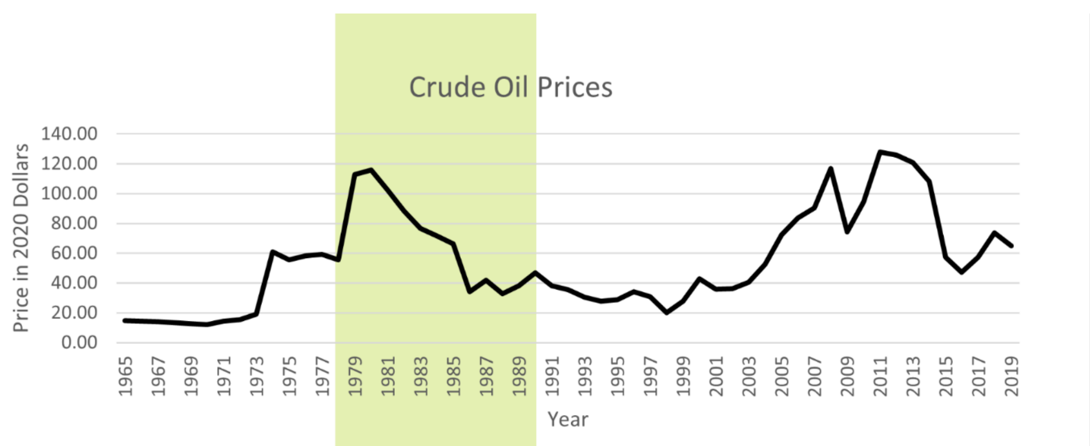
In the three graphs below, the green column highlights the twelve-year period that followed the introduction of CAFE standards, demonstrating the close correlation between changes in the efficiency of the US vehicle fleet, global oil production, and the price of oil. Unless otherwise stated all oil price cited are Brent Crude Prices using data from the BP Statistical Review of World Energy July 202.



Source: Rapid Substitution Researchers, Data from USDOT[7]



Source: Rapid Substitution Researchers, Data from EIA (for period 1973-2017)[8], Hook, Michael (for period 1965-1973)[9]



Source: Rapid Substitution Researchers, Data from BP Statistical Review of World Energy 2021[10]

By regulating for more efficient vehicles, and therefore lowering overall fuel consumption, CAFE standards eventually helped drop oil demand (and production) by about twenty percent (20%).

During the same period, oil prices[11] slowly fell from a high of $120 per barrel in 1980 to below $40 per barrel (inflation adjusted), where they remained until the early 2000s.

In other words, a long-term, twenty-percent (20%) reduction in demand for oil was accompanied by a consistent seventy-percent (70%) drop in the price of oil. It is worth noting that during the first years of the new CAFE standards, OPEC curtailed production in an effort to defend higher prices, a strategy the cartel was eventually forced to abandon in the mid-1980s, resulting in prices that briefly fell below $24 per barrel. [12]

Declining production of oil during this period has also been attributed to economic recession. This would seem an inadequate explanation considering this period also saw economic boom times and that the recession of the early 1980's was relatively short-lived. A long-term, gradual improvement in the American fleet's efficiency would seem a more appropriate explanation for a long-term, gradual depression in oil production matching the same time period as the implementation of CAFE standards.

Academic research[13] shows clearly than most major fluctuations in the price of oil dating back to 1973 are largely explained by changes in the demand for crude oil. While economic recession in the early 1980's put downward pressure on prices, the sustained low prices - lasting a decade - can more accurately be explained by long-term changes brought about by vehicle efficiency standards. While the US percentage of the world's vehicles has fallen as the fleets of other countries, China in particular, have grown, US efficiency standards are still able to influence global oil demand due to the large purchasing power of the US market and its increasing fuel efficiency thereby reducing oil demand globally.

In consideration of the events of the 1980s and a more recent IMF study[14] suggesting that a one-percent (1%) drop in long-term demand will result in a fourteen-percent (14%) drop in long-term price. Rapid Substitution researchers estimate that a five-percent (5%) drop in demand for oil over the course of several years will result in a roughly fifty-percent (50%) drop in the price of oil.

Table 3.1. Oil Demand Price and Income Elasticities
(Subsample, 1990–2009)

	Short-Term Elasticity		Long-Term Elasticity	
	Price	Income	Price	Income
Combined OECD[1] and Non-OECD	–0.019 [–0.028, –0.009]	0.685 [0.562, 0.808]	–0.072 [–0.113, –0.032]	0.294 [0.128, 0.452]
OECD	–0.025 [–0.035, –0.015]	0.671 [0.548, 0.793]	–0.093 [–0.128, –0.057]	0.243 [0.092, 0.383]
Non-OECD	–0.007 [–0.016, 0.002]	0.711 [0.586, 0.836]	–0.035 [–0.087, 0.013]	0.385 [0.193, 0.577]

Source: IMF staff calculations.

Note: Median elasticities and confidence intervals showing 10th and 90th percentile of the distribution in brackets are estimated by Monte Carlo simulations. Long-term elasticities are calculated using a 20-year horizon.

[1]OECD = Organization for Economic Cooperation and Development.

Furthermore, we believe this to be a conservative estimate, and that price drops could be even greater, depending in part on how quickly transitions to other alternative to oil can be made.

As the generation of energy from renewable sources continues to replace energy generated by burning fossil fuels at a more rapid rate, the demand for petroleum products will plummet, along with oil prices, the process we call **Rapid Substitution**.

According to the Transportation Policy Playbook of Breakthrough Energy[15], this transition will happen through a combination of different types of demand reduction. The most obvious is the switch from gasoline-powered personal cars and SUVs to electric equivalents. Other types of demand reduction include electric or hydrogen-powered trucks replacing diesel equivalents; commercial vehicles and delivery trucks switching from gasoline and diesel fuel to electric power; increases in biking (including e-biking and e-scooters) or public transportation; and increases in working from home.

All of these changes will contribute significantly to reducing oil demand, but for this analysis, we will focus on electric vehicles (EVs).

Rapid Growth of EVs

Assuming that every EV sold represents one internal combustion engine (ICE) vehicle not driven, we can conclude that EVs will have the effect of reducing the demand for oil commensurate with the gasoline needs of the ICE vehicle that was replaced. In this way, the replacement of ICE vehicles with EVs will cause downward pressure on the price of oil.

So how many EVs will it take to significantly reduce the price of oil and create financial savings for oil consumers including households and businesses?

In 2020, global EV sales[16] rose by forty-three percent (43%) to more than three million units (representing 4.2 percent of the total car market and despite an overall twenty-percent (20%) decline in car sales).

Most of that EV growth was seen in Europe and China[17], but as the US market begins a more calculated pivot towards electrification, led by government regulations, legacy automakers producing EVs, and new EV manufacturers (e.g., Tesla, Rivian), domestic EV sales will climb at increasing rates.

A relatively conservative 2020 forecast[18] by Deloitte has EV sales in the US rising to twenty-seven-percent (27%) of market share by 2030. Considering that US transportation accounts for roughly 13.5 percent of global oil consumption[19] (60 percent of which is personal vehicles), Deloitte's forecast equates to a greater than three-percent (3%) drop in global oil demand by 2030 *caused by the increase in US EV sales alone*.

Furthermore, that number does not account for the possibility of an even faster transition fueled by a Biden presidency (the Deloitte study was done prior to the 2020 election). Catalysts for swifter substitution could include Biden's call for an all-electric Federal fleet[20], his infrastructure bill[21], which includes funding for 500,000 EV chargers, or the Clean Transit bill[22] introduced by Senators Shumer and Brown.

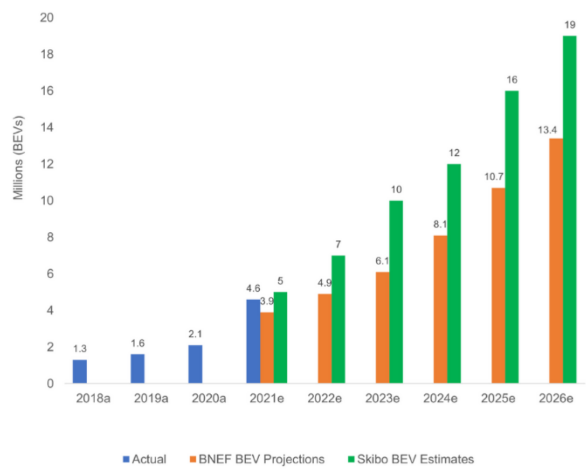
If we set a goal of a fifty-percent (50%) reduction in oil prices, then one major element of achieving that would be to require that enough EVs are sold to reduce demand for oil by five percent (5%). As suggested in the previous section, five percent (5) of all oil produced in 2019, the most recent year for which we have “normal” data, is 1.8 billion barrels.

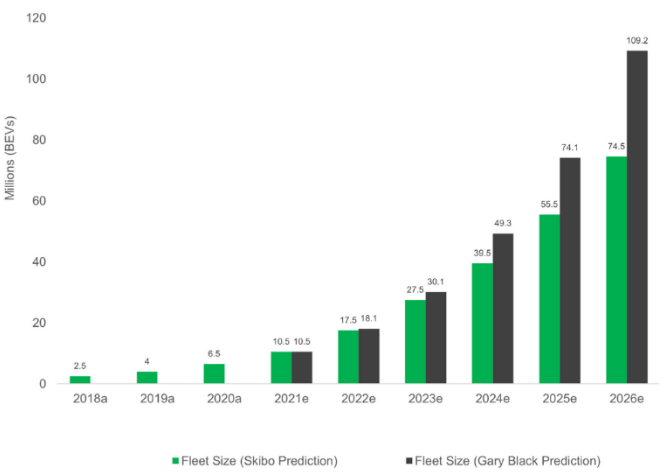
A typical ICE vehicle uses between 11.3 barrels (for cars) and 15.6 barrels (for pickup trucks and SUVs) of oil each year, depending on the type of vehicle. Barrels consumed each year depends on the type of ICE vehicle considered. Trucks and SUVs have lower fuel efficiencies than cars and thus have a greater effect on oil demand destruction. We assume both cars and light trucks will drive approximately 11,500 miles/year.

Considering current vehicle-buying preferences[23], assuming that seventy-two percent (72%) of EVs sold will replace an ICE truck or SUV and twenty-eight percent (28%) will replace a car. It would take selling a total of 126 million EVs (91 million trucks and SUVs and 35 million cars) to reduce oil demand by 1.8 billion barrels (or five percent (5%) of 2019 demand), which would push oil prices below $35 per barrel (1,800,000,000 = .28X*11.3+.72X*15.5).

Obviously, some drivers use more gasoline than others. For example, a contractor who drives their truck around all day uses more gasoline than someone who works from home. The more these “superusers” replace their ICE vehicles with electric ones the fewer vehicles will need to be replaced to reduce oil demand by 5%. In fact, Coltura has a plan to target EV subsidies to these superusers which is a more efficient way to reduce carbon emissions and would drop the price of gasoline faster than non-targeted subsidies.[24]

Using BloombergNEF’s Electric Vehicle Outlook 2021[25], we expect there will be at least this number of EVs on the road by 2029. As supportive government legislation is enacted around the globe, EV manufacturers may reach this milestone even earlier, especially in consideration of recent large (and increasing) EV investments by legacy auto manufacturers[26], new startups[27], and Tesla[28] in EV production.





Source: Rapid Substitution Researchers; BloombergNEF Electric Vehicle Outlook 2021[29]

Calculating Savings and Capturing Return

In 2019, the world spent $2.4 trillion on oil. The average price of a barrel of oil was $64, and average world-wide consumption was 101 million barrels per day. [30]

In 2019, the US alone spent around $479 billion on oil, based on an average price of $64 per barrel and domestic consumption of 20.5 million barrels per day.[31]

Again, based on the historical evidence and market analysis in the previous section, we believe a five-percent (5%) reduction in oil demand will lead to fifty-percent (50%) reduction in oil prices.

In 2019, global oil consumption averaged 101 million barrels per day, so a five-percent (5%) reduction in oil demand would translate to a reduction of just over five million barrels per day.

As shown earlier, there are many potential pathways to achieve this five-percent (5%) reduction. One example is if large percentages of Class 8 trucks (tractor-trailers), delivery trucks, or municipal vehicles (garbage trucks, city buses etc.) were moved away from diesel fuel.

However, for the sake of simplification at this point, we will focus on the ramifications of replacing internal combustion engine (ICE) passenger cars with electric vehicles (EVs).

Financial Implications of EVs

As explained earlier, it would require a switch of 126 million cars (or 90 million light trucks/SUVs and 36 million cars) from ICE to EVs to reduce oil demand by five percent from 2019 levels.

Since the world economy spent around $2.4 trillion on oil in 2019, replacing 170 million ICE passenger cars with EVs would have resulted in a fifty-percent (50%) savings on the cost of oil products, meaning that the world economy would have saved $1.2 trillion a year from the widespread adoption of EVs.

Similarly, since the US economy now spends approximately $479 billion a year on oil products, that fifty-percent (50%) price reduction would save consumers and businesses almost $240 billion a year.

This means that each driver who switches from a gasoline-powered car to an EV lowers global spending on oil by $7,000 and American oil spending by $1,400. Over 10 years, that amounts to a saving of $70,000 per car globally and $14,000 domestically. Naturally, the potential benefits are larger with vehicles that consume more fuel, so switching van and truck fleets from gasoline power to electric power would produce even greater financial rewards.

There are several caveats.

First, there is the fact that every EV sold today will drive most of its lifetime miles before the threshold is reached. But that does not mean they will have no impact on oil prices. To the contrary, the first one-percent (1%) drop in demand will have a greater effect on oil price than successive one-percent (1%) drops, as indicated by the arc of the supply curve.[32]

That being said, it will still require a certain ‘threshold’ number of EVs to be sold before oil prices are affected, since negative demand must first outpace positive demand and push past the ability of producers to force prices upward by tapping existing product reserves or curtailing production.

Won’t Oil Producers Curtail Supply to Keep Prices High?

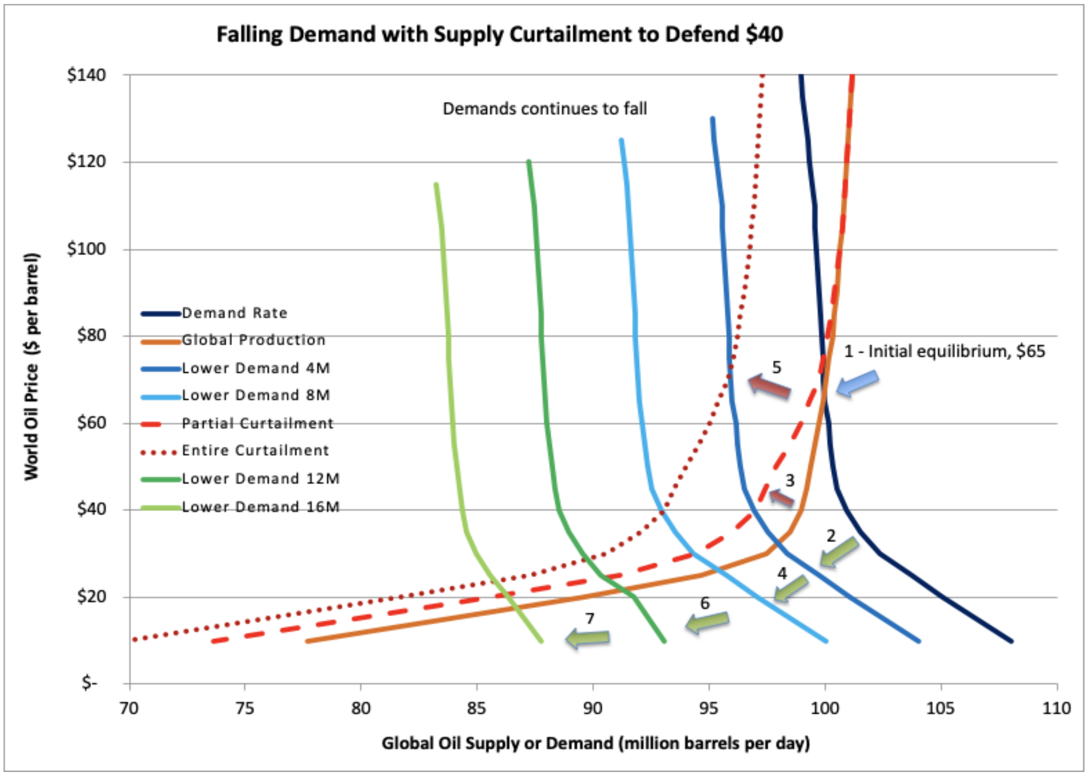
In the short-term, organized efforts by oil suppliers to curtail production can effectively support high prices, as happened in 2009 and then again in 2020, when the price of oil plunged briefly. But production curtailment is only a rational strategy for addressing sudden shocks of limited duration, such as during a sudden supply disruption, economic crisis, or worldwide pandemic.

However, that same curtailment strategy becomes self-destructive in the face of a prolonged, continuous, or permanent systematic decline in demand, such as a sustained revolution in vehicle propulsion. In this way, **Rapid Substitution** is more analogous to the implementation of CAFE auto efficiency standards in the late 1970s, which drove down oil demand (and gasoline prices) for a decade as more fuel-efficient cars gradually replaced their gas-guzzling predecessors.

Once oil suppliers realize that future revenues can only go down in price, the rational strategy for them will be to pump as much existing oil as possible while prices remain relatively high, further diluting their premiums - the “get it while the getting’s good” strategy.

This makes sense because the lion’s share of production expenses are the up-front capital costs of oil exploration, leasing, development, and delivery, while the costs associated with existing operations are much less. Once an oil field is operational, rigs can continue pumping for decades at marginal additional cost to its owner. That means that even without additional sources coming on-line, the existing supply can sustain the increasingly lower prices of demand destruction for years to come.

The graph below tracks the relationship between falling demand and supply curtailment. The initial equilibrium price of $65 **(1)** is disrupted by a drop in demand of four million barrels per day **(2)**. OPEC and other oil producers respond first with a partial curtailment of production **(3)**, and then following another drop in demand of four million barrels per day **(4)**, a more expansive curtailment in production **(5)** to defend the price of $40 per barrel. Demand for oil continues to fall as ICE vehicles are replaced by EVs **(6, 7)** until it reaches an inflection point (5) where producers are forced to give up on their strategy of curtailment. The price of oil continues to fall below $30 per barrel. Notice in this example that a fifteen-percent (15%) drop in demand results in a greater than fifty-percent (50%) drop in the price of a barrel of oil.



Source: EIA, Rapid Substitution Researchers

What About Oil Demand from China?

Every year in the two decades prior to the Covid-19 pandemic, the average global demand for oil rose by an approximate rate of one million barrels per day. Most of that growth came from emerging economies, especially China, which by itself accounted for two-thirds of the increase in global oil consumption during 2019.

It is true that if supplies of oil are curtailed or demand for oil continues to grow at present rates, this could significantly diminish or even cancel out the negative demand generated by EV adoption. However, three factors may mitigate these headwinds:

1. China has already announced that it expects to reach peak oil consumption by 2025, joining OECD countries in their declining demand.
2. New sources of oil will continue to enter the world market, bolstering supplies and depressing prices, (Since exploration of oil wells often takes years and represents most of the cost of production, the sunk costs ensure that production will eventually occur at almost any price).
3. More aggressive regulation of oil consumption will lead to more faster reduction in oil demand.

It is important to note that the above analysis focuses primarily on EV replacement and does not include the falling demand for oil in other sectors of the economy, such as residential heat generation, aviation fuels, petrochemicals, and other industrial and commercial processes.[33]

Public Policy Implications

EV Subsidies

Rapid Substitution provides an important argument in favor of subsidies for electric vehicles. Expanded EV subsidies would encourage mass adoption of EVs causing oil and gasoline prices to drop. The drop in oil and gasoline prices has a huge benefit to consumers and businesses and is an important justification for subsidizing EVs.

The same argument applies to funding other infrastructure that displaces oil consumption such as Greenways, bike lanes and reliable public transportation.

Floating Tax

One way to take advantage of an oil price crash due to an inelastic oil supply is through a floating tax. A tax based on these principles presents the US Federal Government with an opportunity to generate tens of billions of dollars in new revenue.

If, for example, Congress were to establish a floating tax that would be automatically implemented when the cost of oil drops below a certain level (say $50/barrel), the Federal government would raise billions of dollars that could be re-invested in other clean energy efforts. Here's how that math works.

In 2019, American consumers (including business and government entities) spent around $479 billion on oil products. If the price of oil were to drop by fifty percent to $32 a barrel, consumers would be paying around $240 billion for their oil and **not spending** another $240 billion!

At that point, the Federal government triggers the floating tax, collecting the difference between $32 and $50. That's $18 per barrel!

Unlike traditional carbon taxes, this price floor on oil would be less likely to cause public outrage. As oil prices fall below $50/barrel, consumers and businesses will be paying lower prices at the pump and focus less on the fact that global oil prices have fallen even lower.

To provide further context for what these prices mean for consumers at the pump, in May 2017, oil prices averaged around $50/barrel. That month, US consumers paid an average of $2.30 per gallon of gasoline.[34] In November 2019, the average price of oil was $64 per barrel, and the price at the pump was $2.50 per gallon.

Obviously, numerous details must be worked out in order to implement this tax. Where in the value chain would the tax be implemented? Would it float daily, weekly or monthly?

Energy Transition Project Manager

Transitioning from carbon-based to a mostly electric economy means that a lot of stuff (solar panels, heat pumps, electric vehicles etc.) will have to be built.

To get an idea of the scale of the transition required consider the case of electric vehicles. In 2020, 296,000 plug-in light duty electric vehicles were sold in the US, out of a total market of around 15 million light-duty vehicles (cars, SUVs, light trucks). Eventually most new vehicles will need to be electric. That requires a giant increase in manufacturing capacity, major disruptions to existing supply chains, new requirements for workers, and a host of other issues. It's also a huge opportunity, as some industries grow and others are created.

Ensuring this energy transition maximizes benefits and minimizes costs will require some entity to manage the transition. Examples of similar project managers from US history include:

- The War Production Board during World War II which supervised the Arsenal of Democracy
- The Texas Railroad Commission which effectively controlled oil production and oil prices during the middle decades of the 20th century
- Ron Klain's role as White House Ebola Response Coordinator
- A National Climate Advisor with expanded powers

Another example of a similar role is W. Edwards Deming's work on Total Quality Management and the rebuilding of industry in Japan after World War II.

Some entity needs the authority and responsibility to manage the energy transition in order to maximize benefits and minimize disruptions to daily life. There will certainly be big changes to both the economy and how we live our lives. The private sector has an important role in innovation and deployment of clean energy technologies. However, without an enabling policy environment the transition will be too slow and the cost of energy will be too high. With the right leadership and policy environment clean energy can improve our quality of life.

Other Consequences of Rapid Substitution

An accelerated shift from fossil fuel energy to clean energy will have myriad effects or externalities. The more quickly we shift our energy systems, the sooner we will encounter these externalities.

Some of these externalities will be positive, such as less air pollution, less need for the US military to provide security to keep oil flowing, and lower fuel and transportation costs for consumers.

Other externalities will be negative. Because of their batteries, EVs are heavier than gasoline-powered vehicles, so roads will require more maintenance. Much of the money used for that maintenance comes from gasoline taxes, so new sources of funding must be found. Vehicle electrification may lead to job losses in automobile manufacturing and repair.

Other externalities are mixed. Oil producers and investors may end up stuck with "stranded assets" such as oil fields where the cost of production is higher than the value of the oil that would be produced. While not producing that oil is necessary to reduce carbon emissions, it does pose a systemic risk to the existing financial system.

The scale of these externalities makes a compelling argument for an active role from the Federal government to accentuate the positive externalities and mitigate the negative ones.

Below is a short discussion of several select externalities.

Stranded Assets

Accelerating the energy transition would create major problems for those individuals and entities with assets invested in fossil energy.

Consider that of the ten largest oil companies in the world, only one (Saudi Aramco) is profitable with the price of oil at $35/barrel. For most oil companies, prices at that level mean incoming cash flows are unlikely to cover operating costs, and even less likely to provide the huge returns on investment to which oil companies and their shareholders have become accustomed.

Moreover, billions of barrels of petroleum still in the ground would become unprofitable for producers to extract, especially from more expensive and ecologically sensitive sources such as tar sands, deep-water wells, and Arctic drilling. Companies will be forced to write-off these reserves as “stranded assets'' and also incorporate the costs of retiring no-longer-viable wells (known as asset retirement obligations or AROs) into their balance sheets.

Such write-downs of an oil firm's key assets and reserves will have a profound effect both on its market valuation as well as its ability to finance existing operations or fund future ventures, even potentially threatening insolvency. In other words, it is reasonable for investors and other stakeholders to worry about their exposure to Big Oil.

Job Losses in Auto Manufacturing

According to a report by the Economic Policy Institute[35] increases in micro-mobility (including biking, e-biking, and e-scooters), public transportation and increases in work from home, will result in job loss. Even without active policy, a switch to only thirty percent (30%) EVs would cost 75,000 jobs in automobile manufacturing, since more components of EV powertrains are presently produced abroad than for gasoline-powered vehicles and also because EV assembly is less complex and requires fewer labor hours than for assembling gasoline-powered cars.

The report recommends that policymakers, “help meet this coming transformation with investment targeted at boosting the U.S. position in the electric vehicle market and in advanced vehicle technology manufacturing.”

In addition, the simpler nature of EV manufacturing could free up labor to focus on the development and construction of other aspects of the energy transition, such as the deployment of solar and wind farms or the electrification of other industrial aspects of the economy.

Regardless of the mode, there is an important role for the federal government and ideally a dedicated project manager to focus on how to ensure the energy transition benefits companies, workers and consumers.

Rapid Substitution Pays Enormous Social Dividends

The implications that the long-term effects of **Rapid Substitution** will have on oil prices are significant and wide-ranging.

We are all familiar with predicted catastrophic futures, from climate change and unchecked pollution to continued oil exploration in some of the world's most sensitive ecosystems. Accelerating the energy transition will help to mitigate those negative futures.

Today, most oil is sold well above the cost of its production (price being set by the lowest cost production sufficient to meet demand), and therefore it generates tremendous profits for its producers and their investors.

In a **Rapid Substitution** future, those oil profits will be reduced, the difference manifesting as:

- Lower costs for consumers and businesses
- Added revenue for the government to re-invest in the greening of the nation, supporting sustainability
- Mitigation of the environmentally destructive consequences of oil production, transportation, and use.

Achieving **Rapid Substitution** will be neither easy nor inexpensive. However, it will save households and businesses hundreds of billions annually. The savings provide both political support and revenue to accelerate the energy transition even more.

Rapid substitution is better for the planet and for our pocketbooks.

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